A Comparison of Name-Based Content Routing Protocols

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Outline

- Routing In CCN
- NLSR
- DCR
- Performance Comparison
- Conclusion

Routing in CCN

- Problem: Compute the path of minimum cost from each router to each *Prefix* in the network.
- Routing in CCN is inherently more difficult than routing in the traditional IP networks.
- Content objects are cached opportunistically in the network.
- Challenges:
  - Multi-homed instance
  - Find loop-free paths
  - Multi-path routing

Related Works

- ICN architectures implement one or some of the following mechanisms to constructing a path for acquiring data:
  - Flooding requests throughout the whole network.
  - Flooding topology information and the location of publishers.
  - Using source routes to content.
  - Creating spanning tree and use publish-subscribe signaling.
- Directed Diffusion
  - Interests are flooded throughout a sensor network
- DIRECT
  - Similar to directed diffusion
  - Name-based content routing in ad hoc wireless networks subject to connectivity disruption.

Related Works

- NBRP
  - Name-prefix reachability is advertised among content routers
  - Path information is used to avoid permanent loops
- CBCB
  - Establishes a spanning tree of the network
  - Sends publish-subscribe requests for content
- DONA
  - Either global or local IP addressing and IP routing is used.
  - Content requests (FIND messages) gather autonomous-system (AS) path information.

Concept

- ICN architectures
  - location-independent content naming
  - Name resolution and name-based content routing.
- In CCN a routing protocol is needed to
  - Compute next-hops for name prefixes
  - Update FIB to forward interests
- Two routing protocols:
  - NLSR - Named-data Link State Routing
  - DCR - Distance-based Content Routing
- Every piece of content in the network is a named-data object (NDO)
- A set of one or multiple NDOs can be represented by *Prefix*
- Flat or Hierarchical naming
- A router that has local access to the content is called an *Anchor* of the prefix

NLSR

- Link State Routing Algorithm
  - Each router advertises local links and prefixes.
- Introduced to be used in NDN and CCN.
- NLSR relies on two basic mechanisms:
  - Name resolution.
  - Topology-based routing.
- Two types of LSAs
  - Adjacency LSA: The content contains all links of a router.
  - Prefix LSA: The content contains a name prefix registered at the router.
- Floods Link State updates in the network
- Link State Database (LSDB)
  - CCNx Sync: Keep synchronizing LSDB with neighbors.

NLSR

- Relies on NDN "Built-in loop detection"!
- Ranks Interfaces to reach each destination
- Creates Network Topology – Using Adjacency LSA information
- Multiple runs of Dijkstra's algorithm:
  - Remove all interfaces except one
  - Run Dijkstra to calculate cost to reach every other node
  - Repeat for all connected interfaces
- Computes the path cost of using each neighbor
- Ranks neighbors by their costs.

DCR

- Content Routing based on Distance to Destination
- Routers choose what information to share with their peers to preserve ordering (e.g., “the best distance to any instance of content”).
- Supports Route to Multiple Instances
- Establishes a lexicographic ordering of distances to instances of destination
- Routing to
  - *Nearest instances of destination*
  - *Some or all instances of destination*

DCR

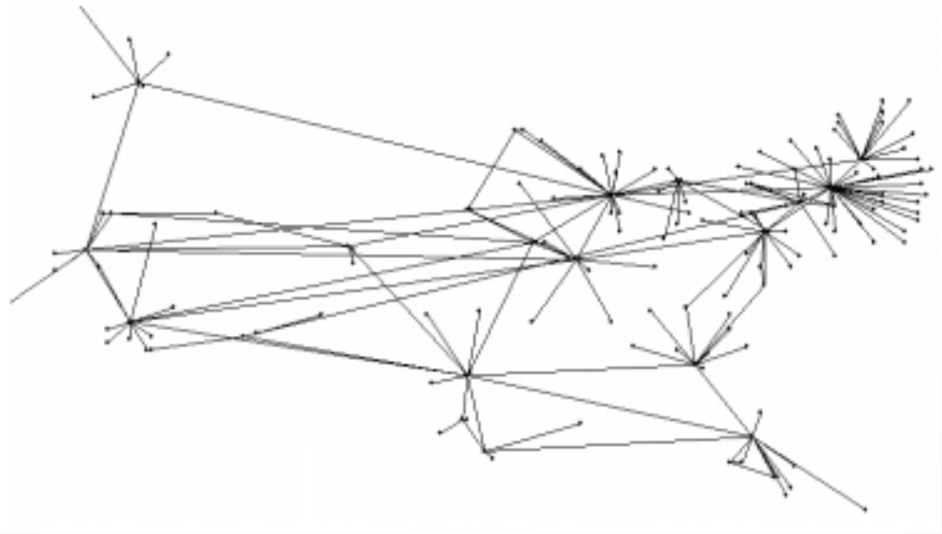
- Updates messages regarding a destination states:
  - Distance
  - Anchor
  - A seq. number created by the anchor

Route to nearest instances of destination:

- Successor-Set Ordering Condition (SOC) select a next hop for destination
- Based on SOC neighbor *k* will be selected as valid next hop when
  - It reports up-to-date information
  - If Router has a finite distance:
    - Neighbor *k* is closer or is at the same distance and has a smaller name
  - If Router does not have a finite distance:
    - Neighbor *k* offers the smallest distance or has smallest name among neighbors offering the same smallest distance.

Simulation

- Simulator: The ns3 simulator tool with extensions for content centric networks – SCoNet
- SCoNet supports CCNx v.1 specifications and messages based on the TLV format
- Network Topology:
    - The AT&T core network (154 nodes and 184 links).



Simulation

- *Network model*
  - The hop count is measured as the distance to a destination
  - 30 nodes are selected as anchors.
  - 180 unique name prefixes.
  - The simulations were run 20 times and different seeds.
  - The anchors are selected randomly
  - Two or more anchors may have some prefixes in common.
- Scenarios:
  - Link Failure
  - Link Recovery
  - Add Prefix
  - Delete Prefix

Simulation

Measurements:

- *Messages:* Total number of control messages transmitted over the network.
  - i-NLSR: Number of Hello messages, adjacency LSAs, and prefix LSAs.
  - DCR: Total number of update messages.
- *Events:* The total number of updates that must be processed by the protocol
  - i-NLSR: Changes in link status or prefix.
  - DCR: Changes in neighbor table
- *Operations:* The total number of operations performed by each protocol to calculate the routing table.
  - Increments whenever an event occurs, and whenever the statements within a loop are executed.
  - The number of operations required to run Dijkstra-SPF algorithm is estimated to be $log_2 N$

Implementation

DCR:

- A node receives an update: checks its information against the information stored in its neighbor table.
- Any changes in the anchor, distance or sequence number of a name prefix: node updates the the neighbor table and schedules a routing update.
- A router waits to receive updates from other neighbors before changing its routing table.
- A router reports the updated routing information to its neighbors in its next update message.
- Each update message contains the information regarding all the prefixes known to the router .
- Sends update messages each 10-second interval.

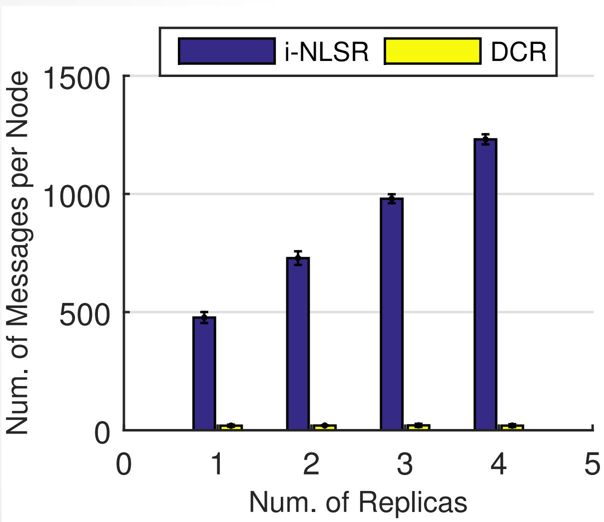
Implementation

NLSR:

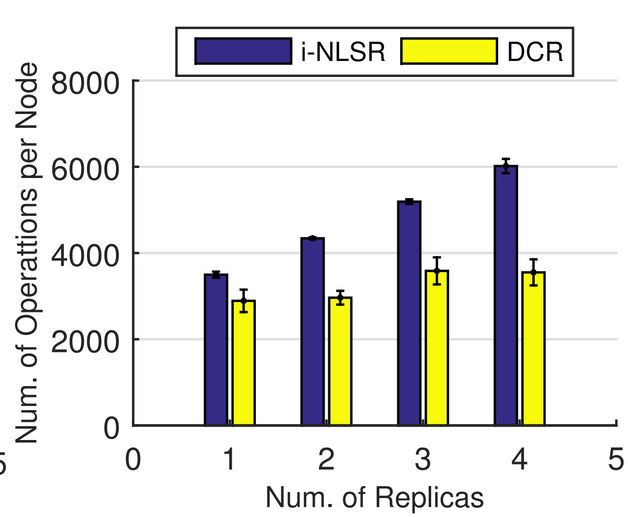
- A router receives an LSA: updates its LSDB and schedules the routing update
- Adjacency LSA: the router ranks its interfaces and updates its routing table
- Prefix LSA: it maps the name prefix to the destination and ranks the next-hops based on routing table information
- If two or more routers advertise the same name prefix, the faces are ranked based on distance to closest router.
- Sends *info messages* every 10 seconds.
- Sends LSA whenever it detects a change in topology or local prefixes.

Results

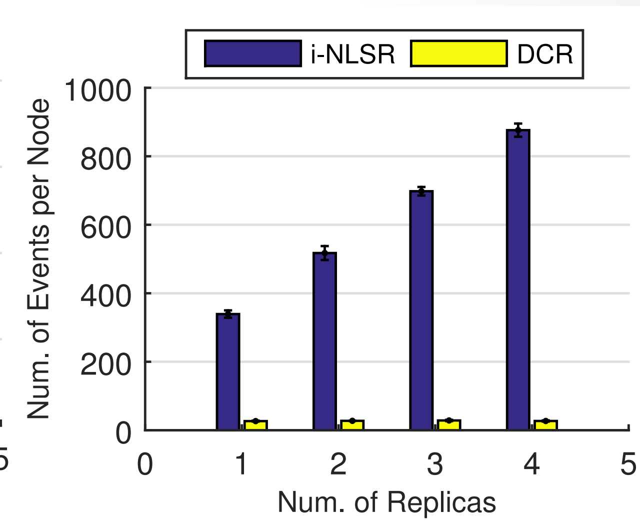
- Initialization:
  - Add a new node
  - Node Recovery



Number of messages



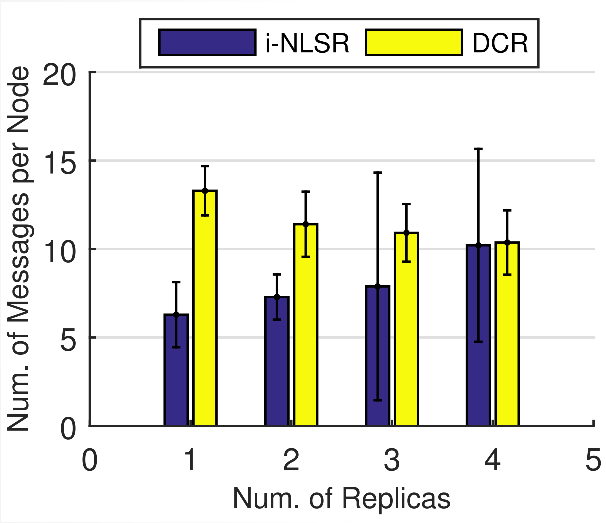
Number of Operations



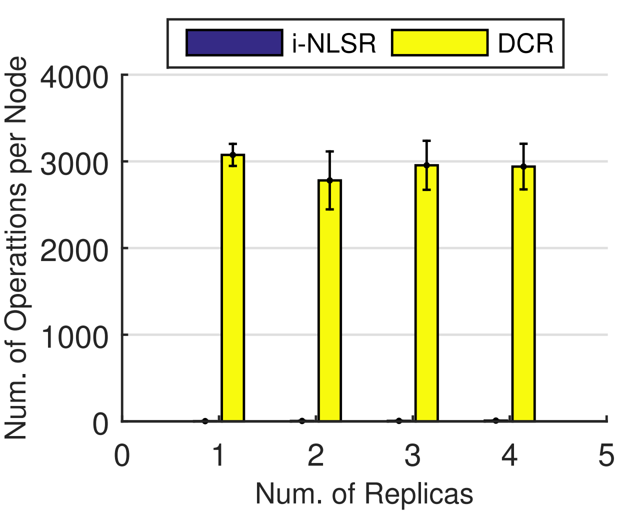
Number of Events

Results

- Add new Prefix



Number of messages



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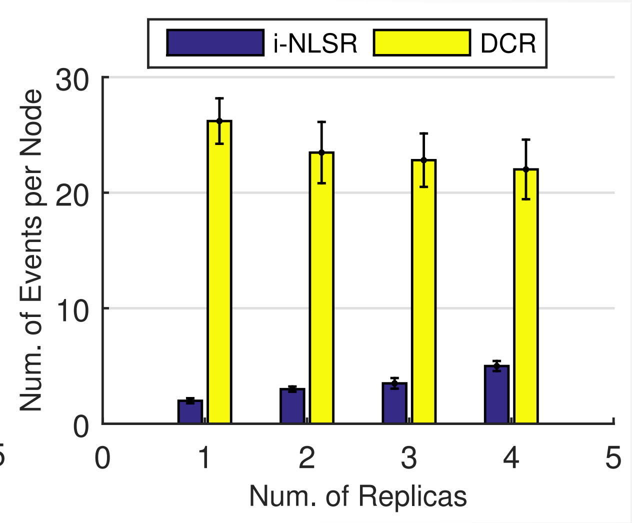
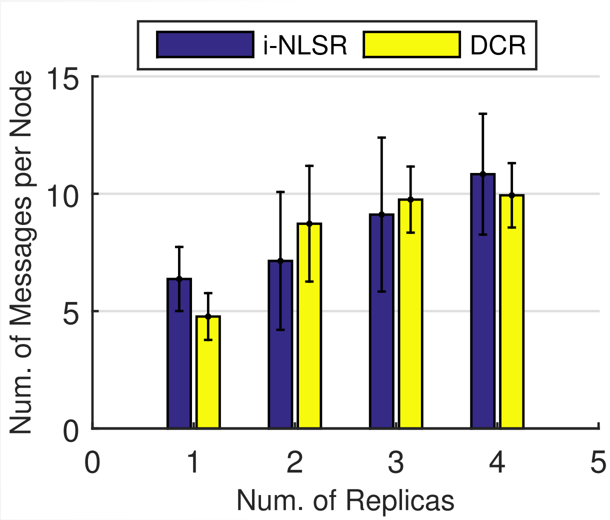


Number of Events

Results

- Delete a Prefix



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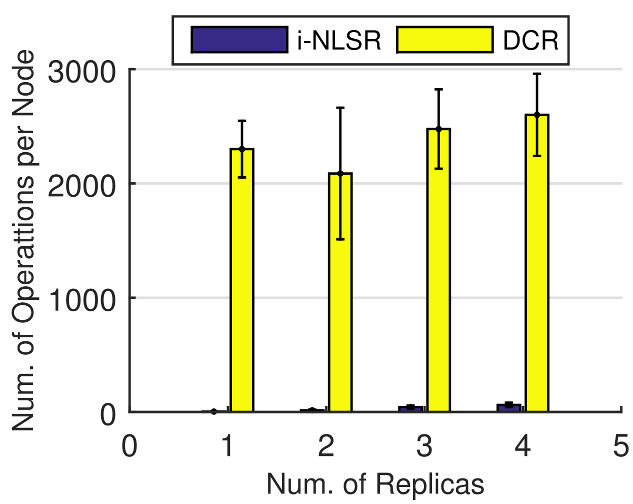

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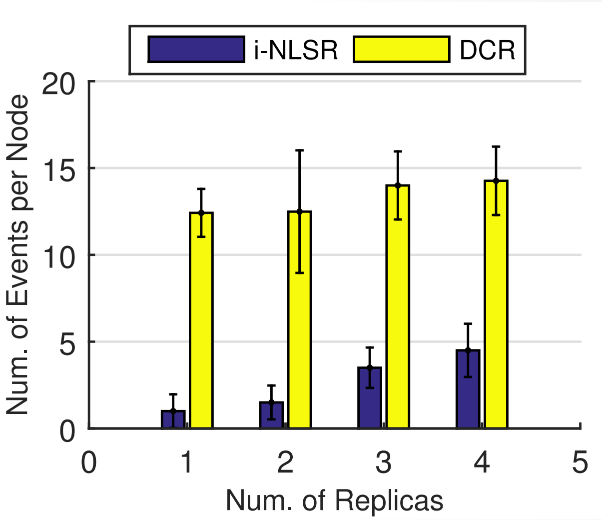
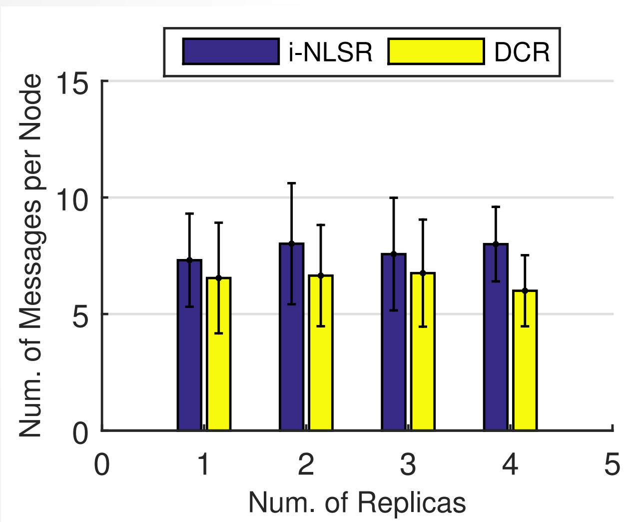


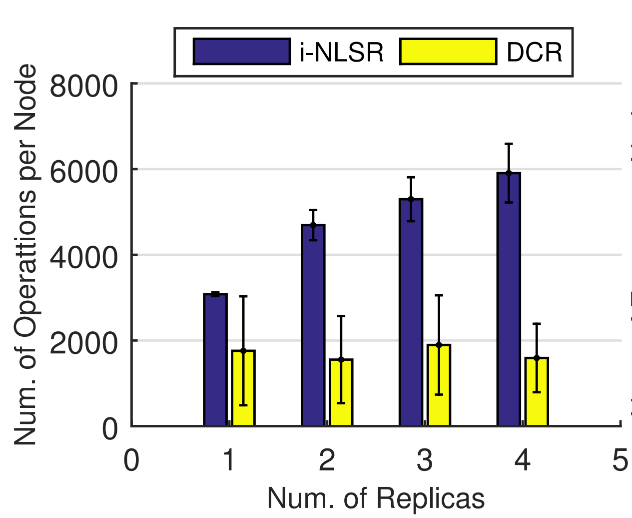
Number of Events

Results

- Link Failure



Number of messages



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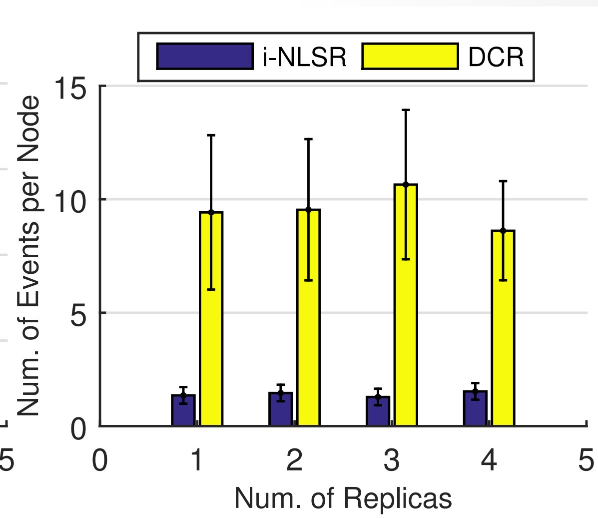
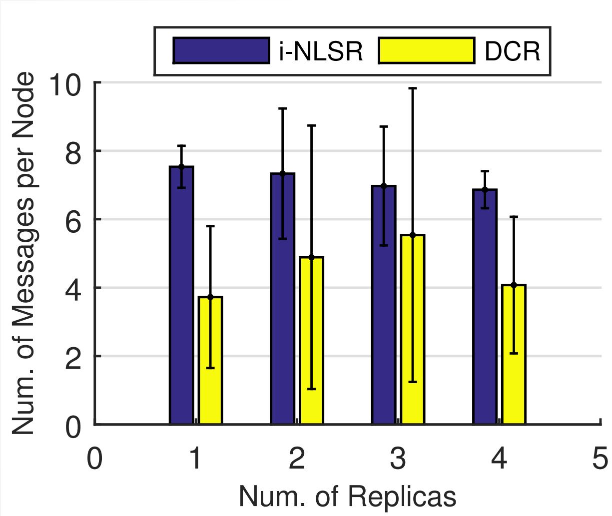


Number of Events

Results

- Link Recovery



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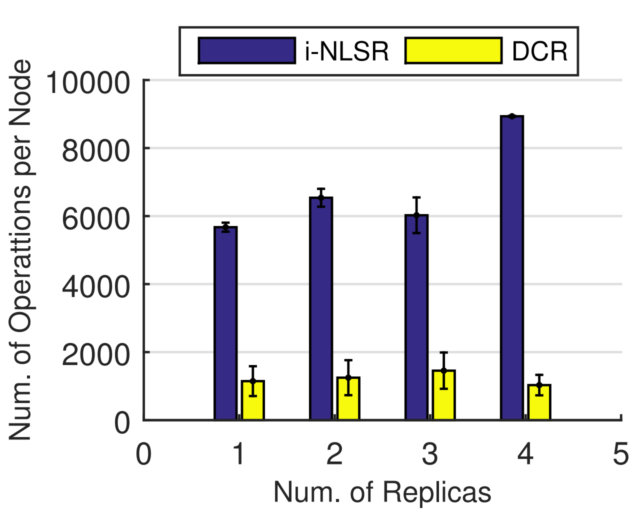

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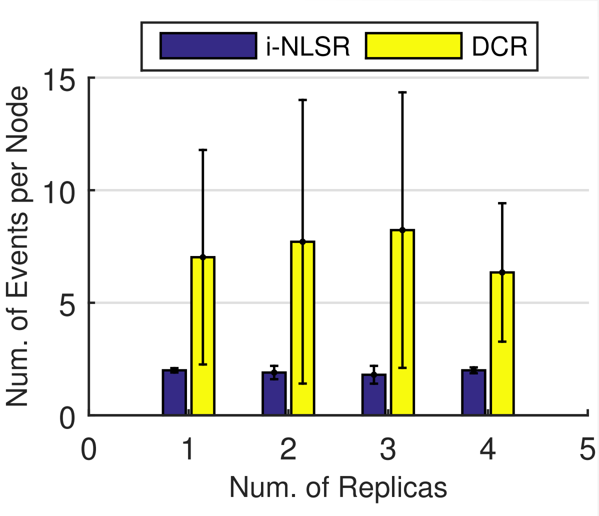

Number of Events

Conclusion

- The overhead in NLSR becomes an issue when the average number of replicas per name prefix grows beyond two.
- For DCR to work efficiently, update messages in DCR should describe updates made to distances to name prefixes since the last update was sent, rather than having each update message contain information about all name prefixes.
- Content routing approaches in which routers are not required to send periodic updates should be investigated for both link-state and distance-vector approaches.
- The importance of sender-initiated signaling mechanisms in CCN and NDN should be quantified.

- Thank You!
- Any Question?